APPENDIX E

ELECTRICAL ENGINEERING DESIGN CRITERIA

E.1 INTRODUCTION

Project design, engineering, procurement, and construction activities will be controlled in accordance with various predetermined standard practices and project-specific programs/practices. An orderly sequence of events for project implementation is planned, consisting of the following major activities:

- Conceptual design.
- Licensing and permitting.
- Detailed design.
- Procurement.
- Construction and construction management.
- Checkout, testing, and startup.
- Project completion.

This appendix summarizes the codes and standards, standard design criteria, and industrial good practices that will be used during the project. The general electrical design criteria defined herein form the basis of the design for project electrical components and systems. More specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used. Codes, standards, and general criteria selected during the detail design phase of the project may vary from the information indicated in this appendix per specific project or design requirements.

Section E.2 summarizes the applicable codes and standards, and Section E.3 includes the general design criteria for motors, power and control wiring, protective relaying, classification of hazardous areas, grounding, lighting, heat tracing, lightning protection, raceway and conduit, and cathodic protection.

E.2 DESIGN CODES AND STANDARDS

The design and specification of all work shall be in accordance with the laws and regulations of the federal government and the state of California, and local codes and ordinances. A listing of the general codes and industry standards to be used in design and construction follows:

- The American Bearing Manufacturers Association (ABMA).
- American National Standards Institute (ANSI).
- American Society for Testing and Materials (ASTM).
- Insulated Cable Engineers Association (ICEA).

- Institute of Electrical and Electronics Engineers (IEEE).
- Illuminating Engineering Society (IES).
- National Electrical Code (NEC).
- National Electrical Manufacturers Association (NEMA).
- National Electrical Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Occupational Safety and Health Administration (OSHA).
- Underwriters' Laboratories (UL).
- Uniform Building Code (UBC).
- American Gas Association (AGA).

Other recognized standards will be used where required to serve as guidelines for design, fabrication, and construction when not in conflict with the above listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

Seismic design criteria from either the Uniform Building Code or IEEE will be used.

The following laws, ordinances, regulations, and standards (LORS) have been identified as applying to electrical engineering design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more conservative code will be met.

E.2.1 Federal

None are applicable.

E.2.2 State

- Title 24 California Code of Regulations (CCR) Sections 2-5301 et seq., Energy Conservation.

- Title 24 CCR Section 2-6101 et seq., Special Electrical Systems.

- Title 24 CCR Section 3-089 et seq., State Electrical Systems.

- Warren-Alquist Act (WAA) and the California Energy Commission (CEC) siting regulations require submittal of detailed information describing measures proposed to ensure safe and reliable operation of the facility and the design and feasibility of all systems and components related to the generation of power.

E.2.3 County

None are applicable.

E.3 ELECTRICAL DESIGN CRITERIA

E.3.1 Electric Motors

E.3.1.1 General Motor Design Criteria

These paragraphs outline basic motor design guide parameters for selecting and purchasing electric motors. The following design parameters will be considered:

- Motor manufacturer.
- Environment, including special enclosure requirements.
- Voltage, frequency, and phases.
- Running and starting requirements and limitations and duty cycle.
- Motor type (synchronous, induction, DC, etc.) and construction.
- Power factor.
- Service factor.
- Speed and direction of rotation.
- Insulation.
- Bearing construction, rating life of rolling elements, and external lube oil system for sleeve or plate bearings.
- Ambient noise level and noise level for motor and driven equipment.

- Termination provisions for power, grounding, and accessories.
- Installation, testing, and maintenance requirements.
- Special features (shaft grounding, temperature and vibration monitoring, surge protection, etc.).
- Motor space heater requirements.

E.3.1.1.1 <u>Safety Considerations for Motors</u>. The Occupational Safety and Health Administration rules will be followed for personnel protection. Belt guards will be specified for personnel safety and, when required, to prevent foreign objects from contacting belt surfaces. Guard screens will be provided over motor enclosure openings to prevent direct access to rotating parts. Electrical motors will be adequately grounded.

Motors in hazardous areas will conform to applicable regulatory requirements and will be UL labeled. Motor electrical connections will be terminated within oversized conduit boxes mounted to the motor frame.

E.3.1.1.2 <u>Codes and Standards</u>. Motors will be designed, manufactured, and tested in accordance with the latest applicable standards, codes, and technical definitions of ANSI, IEEE, NEMA, and ABMA, as supplemented by requirements of the specifications.

E.3.1.1.3 <u>Testing Requirements</u>. Each type of AC and DC machine will be tested in accordance with the manufacturer's routine tests at the factory to determine that it is free from electrical or mechanical defects and to provide assurance that it meets specified requirements. The following criteria and tests will be used in testing each type of machine:

- Integral horsepower, three-phase, 460 volt induction motors:
  - Routine tests listed in NEMA MG-1, Routine Tests for Polyphase Medium-Induction Motors.
  - Test procedures will be in accordance with IEEE, Test Procedure for Polyphase Induction Motors and Generators.
- Induction motors rated above 600 volts:
  - Routine tests listed in NEMA MG-1, Large Machines-Induction Machines-Tests, will be performed on each motor.

- The following additional tests and inspections will be performed on each motor larger than 500 horsepower:

  (1) Locked-rotor current at fractional voltage. Current balance.

  (2) Length of time of bearing test and final temperature rise of bearing.

  (3) A statement that bearings have been inspected and approved for shipment.

  (4) Insulation resistance time curve and polarization index for motors with formed-coil stators.

  (5) Final value of motor noise levels including statement that there is no objectionable single frequency noise.

  (6) Final air gap measurements (single air gap).

- Motors that are specified to have complete tests performed on either the furnished motor or an electrically duplicate motor will require the following tests:

  (1) Temperature.

  (2) Percent slip.

  (3) No-load saturation curve.

  (4) Locked-rotor saturation curve, including locked-rotor torque, current, and power.

  (4) Speed-torque and speed-current curves at rated voltage and at minimum starting voltage.

  (6) Efficiency at full, three-fourths, and one-half loads.

  (7) Power factor at full, three-fourths, and one-half loads.

• Direct current motors:

- The standard routine tests and inspections will be performed on each motor. These will include the following:

(1) High potential dielectric test.
(2) Measurement of resistance of all windings.
(3) Inspection of bearings and bearing lubrication system.

(a) No-load running armature current, shunt field current, and speed in revolutions per minute, at rated voltage.

(b) Full load armature current, shunts field current, and speed in revolutions per minute, at rated voltage.

– Test procedures will be in accordance with NEMA MG-1 Tests and Performance DC Small and Medium Motors.

E.3.1.1.4 <u>Electrical Design Criteria</u>. Special requirements for individual motors and specifications for special application motors will be included in individual specification technical sections.

<u>Rating</u>. The motor nameplate horsepower multiplied by the motor nameplate service factor will be at least 15 percent greater than the driven equipment operating range maximum brake horsepower. For motors with 1.15 service factor, the maximum load horsepower will not exceed the motor nameplate.

Motor operating voltages (excluding motor-operated values) are tabulated as follows:

Voltage Horsepower	Nominal System Voltage	Motor Nameplate Voltage	Frequency, Hz	Phases
Up to 1/3	120	115	60	1
1/2 and less than or equal to 249 (except for special applications)	480	460	60	3
250 and larger	4,160	4,000	60	3
DC motors	125	125	DC	

This table is intended as a general guide; however, individual conditions such as distance from power source, voltage drop, etc., may dictate deviations from the stated horsepower/voltage criteria.

Emergency motors will operate continuously at the nominal system voltage with any supply voltage between 80 percent and 112 percent of the nominal system voltage.

Motors will be designed for full voltage starting and frequent starting where required and will be suitable for continuous duty in the specified ambient conditions. Intermittent duty motors will be selected where recognized and defined as standard by the equipment standards and codes.

The torque characteristics of all induction motors will be as required to accelerate the inertia loads of the motor and driven equipment to full speed without damage to the motor or the equipment at any voltage from 90 percent to 110 percent of motor nameplate voltage except those to be individually considered. A voltage drop greater than 10 percent from the specified motor nameplate rating will be individually considered for proper motor starting and operating.

Temperature Considerations. Integral horsepower motors will be designed for an ambient temperature of 40° C. Motors located in areas where the ambient temperature exceeds 40° C will be designed for that ambient condition.

Windings and Insulation. All insulated windings will have a Class F nonhygroscopic insulation system with Class B temperature rise and ambient temperature in accordance with NEMA MG-1 standards. When ambient temperatures greater than 40° C are specified, the allowable temperature rise will be reduced in accordance with NEMA MG-1 standards.

All insulated stator winding conductors and wound rotor motor secondary windings will be copper.

The insulation resistance corrected to 40° C will be not less than motor rated kV+1 megohms for all windings.

Where required, the windings will be treated with a resilient, abrasion resistant material.

Overspeeds. Squirrel-cage and wound-rotor induction motors, except crane motors, will be so constructed that, in an emergency of short duration, they will withstand, without mechanical injury, overspeeds above synchronous speed in accordance with the table as listed in NEMA MG-1, Overspeeds for Motors.

Space Heaters. Space heaters will be sized as required to maintain the motor internal temperature above the dew point when the motor is idle. Motor space heaters will not cause winding temperatures to exceed rated limiting values nor cause thermal protective device overtemperature indication when the motor is not energized.

In general, all NEMA series 180 frame size motors or larger will have 120 volt, single-phase, 60 hertz space heaters. The voltage rating of the heaters will be at least twice their operating voltage of 120 volts. All 4,000-volt motors will have space heaters. Space heaters rated 10 amps and less will be suitable for operation on 120 volts, single-phase, 60 hertz. Heaters rated above 10 amps will be suitable for operation on 208 volts, three-phase, 60 hertz. Heaters will be located and insulated so they do not damage motor components or finish.

Space heater leads will be stranded copper cable with 600-volt insulation and will include terminal connectors. Space heater leads will be wired to a separate terminal housing on 4,000-volt motors.

Nameplates. All motor nameplate data will conform to NEMA MG-1 requirements. The following additional nameplate data will be included for 4,000 volt rated motors:

- Manufacturer's identification number.
- Frame size number.
- Insulation system class designation.
- Maximum ambient temperature for which the motor is designed or the temperature rise by resistance.
- Service factor.
- Starting limitations.
- Direction of rotation and voltage sequence.
- ABMA bearing identification number for motors furnished with rolling element bearings.
- For motors with connections to an external lubricant recirculating system, or with an integral forced lubrication system, required oil pressure and oil flow.
- For motors designed for service in hazardous areas:
  - Location class and group designation.
  - Maximum operating temperature value or operating temperature code number.

Environment. Location of individual motors within the plant will determine ambient temperature, corrosive environment, hazardous environment, and humidity to be experienced by the motors. These conditions will be considered in the purchase specification.

Allowable Noise. The motor sound level will conform to the motor driven equipment assembly overall sound level requirements. In no case will the average no-load sound pressure level, reference level 20 micropascals, produced by the motor, exceed 90 dBA free field at 1 meter for motors rated 200 horsepower and less, and at 2 meters for motors rated above 200 horsepower.

E.3.1.2 4,000-Volt Squirrel-Cage Induction Motors

E.3.1.2.1 Design and Construction. Design and construction of 4,000-volt motors will be coordinated with the driven equipment requirements.

Motor power lead terminal housings will be adequately sized to terminate the power conductors. For 4,000-volt motors, the power lead terminal housing will also be large enough to provide working space for field fabrication of stress cones within the housing and to contain the stress cones after installation.

Separate terminal housings will be provided for:

- Motor power leads.
- Motor accessory leads.
- Motor temperature detector leads.

All leads will be wired into their respective terminal housings. All motor leads and their terminals will be permanently marked in accordance with the requirements of NEMA MG-1, Part 2. Each lead marking will be visible after taping of the terminals.

Motors designed to rotate in only one direction will have the direction of rotation marked by an arrow mounted visibly on the stator frame near the terminal housings or on the nameplate, and the leads marked for phase sequence T1, T2, and T3 to correspond to the direction of rotation and supply voltage sequence.

All outdoor motors will be TEFC with NEMA waterproof features or WP Type II with filter. Indoor motors in wet areas will be fully guarded, with dripproof enclosures.

Motors for outdoor service will have all exposed metal surfaces protected with a corrosion-resistant polyester paint or coating.

In addition to the preceding requirements for outdoor service motors, totally enclosed motors will have enclosure interior surfaces and the stator and rotor air gap surfaces protected with a corrosion-resistant alkyd enamel or with polyester or epoxy paint or coating. Bolts, nuts, screws, and other hardware items will be corrosion-resistant or heavy cadmium plated metal. A rotating labyrinth shaft seal will be furnished on the shaft extension end of the motor.

Weather protected Type II enclosures will have standard space heaters, and removable, recleanable, impingement type air filters.

Squirrel-cage induction motors will have rotors of fabricated copper alloy, cast aluminum, or fabricated aluminum alloy. Fabricated aluminum alloy will only be used where the manufacturer has demonstrated the reliability of his design and low inertia loads.

E.3.1.2.2 Insulation. All motors will be furnished with Class F or Class H insulation systems, provided the temperature rise is based on Class B maximum. An insulation resistance time curve corrected to 40° C for determining the polarization index for motor stator windings will be taken immediately before making the final high potential ground test. Each stator phase will be tested separately to ground, with other phases grounded. Motors will be tested at not less than 5,000 VDC. The ambient temperature, winding temperature, and relative humidity values will be included with the recorded data. The polarization index will not be less than 3.0. An insulation-to-ground dielectric test will be made on the motor windings at a value of two times rated voltage + 1,000.

E.3.1.2.3 Bearings. Horizontal motors, except motors for belted drives, will have split sleeve bearings of oil ring type, unless required otherwise.

Sleeve bearings on horizontal motors will be designed and located centrally with respect to running magnetic center to prevent the rotor axial thrust from being continuously applied against either end of the bearing. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized.

When sleeve bearings are not specified, horizontal motors will have antifriction bearings.

Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation, without damage to the bearings, the motor frame, or other motor parts.

Motors furnished with spherical roller thrust bearings will also be furnished with ball or deep groove radial guide bearings. The guide bearings will be locked to the shaft so that the guide bearing will take upward thrust and to assure that the thrust bearing is always loaded. If spring loading is furnished, the guide bearing will not be preloaded during normal operation.

Bearing lubricants will contain a corrosion inhibitor. The type and grade of lubricant will be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant filling device.

Insulation will be provided on bearing temperature detectors and on oil piping connections when required to prevent circulation of shaft current through bearings.

Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

E.3.1.2.4 Bearing Temperature Detectors. One Type E thermocouple per motor bearing, complete with detector head and holder assemblies as required, will be furnished. Thermocouple lead wire insulation will be color-coded with standard colors to represent the thermocouple metals.

E.3.1.2.5 Winding Temperature Detectors. Two resistance platinum temperature detectors (RTDs) per winding will be furnished, installed, and wired complete. Temperature detectors will normally be three-wire type RTDs.

E.3.1.2.6 Temperature Detector and Terminal Block Requirements. Temperature detectors will be ungrounded, with detector leads wired to terminal blocks furnished in the accessory terminal housings. A grounding terminal for each temperature detector will be included with the detector lead terminals. The grounding terminals will be wired internally to a common ground connection in each terminal box. The internal wiring will be removable.

E.3.1.3 460 Volt Integral Horsepower Motors

E.3.1.3.1 Design and Construction. Design and construction of each 460 volt integral horsepower motor will be coordinated with the driven equipment requirements and the requirements of NEMA MG1 Standards.

Motors will have TEFC enclosures unless they are located in hazardous areas. Motors for service in hazardous areas will be individually considered for types of enclosure depending upon the classification, group, and division of the hazardous area in question.

Motors for outdoor service will have all exposed metal surfaces protected with a corrosion-resistant polyester paint or coating.

Motor power lead terminal housing will be sized to allow for ease in terminating the incoming power cable. Space heater leads will also be in this terminal housing.

E.3.1.3.2 <u>Bearings</u>. The motor manufacturer will determine the type of bearings to be furnished based upon the load, speed, and thrust conditions of the driven equipment.

Antifriction bearings will be grease lubricated, designed to minimize the likelihood of overlubricating, sealed to protect against dust entry and loss of lubricant, and self-lubricating and regreaseable.

All bearing mountings will be designed to prevent the entrance of lubricant into the motor enclosure of dirt into the bearings. Grease fittings for lubrication will be arranged for safe, easy addition of lubricant from the outside of the motor while the motor is in service. Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

Horizontal motor bearings will have an L-10 rating life when operating under the load, speed, and thrust requirements of the driven equipment of not less than 40,000 hours for direct coupled or gear driven service and not less than 20,000 hours for belt or chain connected service. Vertical motor bearings will have an L-10 rating life of not less than 40,000 hours.

E.3.1.4 <u>Direct Current Machines</u>

E.3.1.4.1 <u>Design and Construction</u>. All direct current machines will be designed and constructed for continuous operation and in accordance with the requirements of NEMA MG-1.

Motors for operation on an AC rectified power source will be rated, designed, and factory tested in accordance with NEMA MG-1 requirements for the form factor of the rectified power source. The rated form factor will be obtained from the rectifier manufacturer.

E.3.1.4.2 <u>Service Factor</u>. For motors furnished with a service factor greater than 1.0, the motor nameplate will indicate the horsepower rating at 1.0 service factor, and the service factor. The motor will be designed to provide a continuous horsepower capacity equal to the rated horsepower at 1.0 service factor multiplied by the specified motor service factor without exceeding the total limiting temperature rise stated in these specifications for the insulation system and enclosure specified.

E.3.1.4.3 <u>Insulation and Windings</u>. All insulated windings will have a minimum of Class B nonhygroscopic, or acceptable equivalent, sealed insulation system. All insulated winding conductors will be copper.

E.3.1.4.4 <u>Armatures and Brushes</u>. Commutator bars will be fabricated of silver bearing copper, free of cracks, pits, slivers, and similar imperfections. Bars will be insulated with mica segments, assembled and seasoned as a unit, properly undercut, and securely mounted on the shaft. The area in back of the armature commutator risers will be packed with an epoxy compound and cured. Coil end connections to the risers will be soldered with high temperature pure tin solder, brazed, or tungsten inert gas welded.

Brush holders will be fabricated of nonferrous materials, located accurately, and mounted securely to position the brushes on the armature. Brush holder pockets will be sized to permit proper movement of the brushes. Means for adjusting brush pressures and brush assembly ring will be provided. A stop device will be furnished to prevent the brush terminal from scoring the commutator.

Brushes will be carbon type and will be famished with insulated shunts sized for the rated brush current.

Successful commutation in accordance with NEMA standards will be maintained over the load range encountered in service.

Extra large openings will be provided for ease of inspection, pressure adjustment and replacement of brushes, and for brush assembly ring adjustment.

E.3.1.4.5 Bearings. All bearings will be self-lubricating, will have provisions for relubrication, and will be designed to operate in any position or at any angle.

E.3.1.5 Fractional Horsepower Motors

Type, design, and construction of each general, special, and definite purpose fractional horsepower motor will be coordinated with the driven equipment requirements and will be in accordance with the requirements of NEMA MG-1. Motors will be provided with Class B or Class F insulation classification. Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

Motors will be totally enclosed (TEFC or TENV) unless specified otherwise.

Motors for outdoor service will have all exposed metal surfaces protected, where practical, with a corrosion-resistant polyester paint or coating. Enclosure exterior and interior surfaces, air gap surfaces, and windings will be protected with a corrosion-resistant epoxy paint or coating.

All bearings will be self-lubricating, will have provisions for relubrication, and will be designed to operate in any position or at any angle.

E.3.1.6 Motor Operators for Nonmodulating Valve, Gate, or Damper Service

The following requirements are applicable to all electric operators required for nonmodulating motor operators.

E.3.1.6.1 Rating, Design, and Construction. Motors will be designed for high torque, reversing service in a 40° C ambient temperature. Motors will have Class F insulation classification. Requirements of NEMA MG-1 and MG-2 will apply.

Motors will be rated 460 volts, three-phase, 60 hertz unless otherwise indicated. The DC motors will be rated 120 volts DC to operate from a nominal 125 volt battery.

The motor time rating for normal opening and closing service will be not less than whichever of the following is greatest:

- As required for three successive open-close operations.
- As required for the service.
- Fifteen minutes at maximum driven equipment torque in a 50° C (122° F) ambient temperature.

Sufficient torque will be provided to operate against system torque at 90 percent nominal voltage for AC motors and at 85 percent nominal voltage for DC motors.

Motors will be provided with NEMA 4 enclosures unless specified otherwise.

Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

E.3.1.6.2 Bearings. Double-shielded, grease prelubricated, regreaseable antifriction bearings will be furnished. Motor leads will be terminated in the limit switch compartment.

E.3.1.6.3 Space Heaters. All motor operators 7-1/2 horsepower and larger will be supplied with 120 volt AC, single-phase, space heaters. Space heater leads will be terminated in the limit switch compartment.

E.3.2 Power and Control Wiring

E.3.2.1 <u>Design Conditions</u>

In general, conductors will be insulated on the basis of a normal maximum conductor temperature of 90° C in 40° C ambient air, with a maximum emergency overload temperature of 130° C and a short-circuit temperature of 250° C. In areas with higher ambient temperatures, larger conductors will be used or higher temperature rated insulation will be selected. Conductor size and ampacity will be coordinated with circuit protective devices. Cable feeders from 4.16 kV switchgear to power equipment will be sized so that a short-circuit fault at the terminals of the load will not result in damage to the cable before normal operation of a fault interrupting device (i.e., before the breaker is tripped or fuse is melted).

Instrument cable will be shielded and twisted to minimize electrical noise interference as follows:

- Aluminum-polyester tape with 100 percent coverage and copper drain wire will be used for shielding.
- Low-level analog signal cables will be made up of twisted and shielded pairs.
- Except where specific reasons dictate otherwise, cable shields will be electrically continuous. When two lengths of shielded cable are connected together at a terminal block, a point on the terminal block will be used for connecting the shields.
- For multi-pair cables using individual pair shields, the shields will be isolated from each other.

To be effective, instrument cable shields will be grounded on one end as follows:

- The shields on grounded, as well as ungrounded, thermocouple circuits will be grounded at the thermocouple well.
- Multi-pair cables used with thermocouples will have individually isolated shields so that each shield will be maintained at the particular couple ground potential.
- Each resistance temperature detector (RTD) system will be a three-wire system consisting of one power supply and one or more RTDs and will be grounded at only one point.

- RTDs embedded in windings of transformers and rotating machines will be grounded at the frame of the respective equipment.

- The low or negative potential side of an instrument signal pair will be grounded at the same point where the shield is grounded. Where a common power supply is used, the low side of each signal pair and its shield will typically be grounded at the power supply.

E.3.2.2 <u>Conductors</u>

E.3.2.2.1 <u>Design Basis</u>. Electrical conductors will be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served. The type of cable used will be determined by individual circuit requirements and individual equipment manufacturer's recommendations.

E.3.2.2.2 <u>Cable Ampacities</u>. The maximum ampacities for any cable will be in accordance with the NEC. In addition to ampacity, special requirements such as voltage drop, fault current availability, and environment will be taken into consideration when sizing cable.

E.3.2.3 <u>Insulation</u>

Cable insulation and construction will be as follows.

E.3.2.3.1 <u>Flame Retardance</u>. To minimize the damage that can be caused by a cable fire, cables will have insulations and jackets with nonpropagating and self-extinguishing characteristics. At a minimum, these cables will meet the flame test requirements of IEEE, using a gas-burner flame source. These characteristics are essential for cables installed in electrical cable tray in the plant.

E.3.2.3.2 <u>Medium Voltage Power Cable</u>. Shielded power cable with minimum five kV class insulation will supply all 4.16 kV service and will be routed in trays, conduits, or underground duct banks.

E.3.2.3.3 <u>Low Voltage Power Cable, 600 Volts</u>. Nonshielded power cable with 600 V class insulation will supply power to loads at voltage levels of 480 VAC and below and 125 VDC and below. Cables will be routed in trays, conduits, or ducts.

E.3.2.3.4 <u>Control Cable 600 Volts</u>. Nonshielded control cable with 600 V class insulation will be used for control, metering, and relaying. Cables will be routed in trays, conduits, or ducts.

E.3.2.3.5 Instrument Cable 300 or 600 Volts. Instrument cable will be used for control and instrument circuits that require shielding to avoid induced currents and voltages.

E.3.2.3.6 Thermocouple Extension Cable. Thermocouple extension cable will be used for extension leads from thermocouples to junction boxes and to instruments for temperature measurements. Cables will be routed in trays or conduits.

E.3.2.3.7 High Temperature Cable. High temperature cable will be used for wiring to devices located in areas with ambient temperatures normally above 75° C. Cables will be routed in conduit. Cable lengths will be minimized by terminating the cable at terminal boxes or conduit outlet fittings located outside the high temperature area and continuing the circuit with control or thermocouple extension cable.

E.3.2.3.8 Lighting and Fixture Cable. Lighting and fixture cable designations and conductor sizes will be identified on the drawings. The wire used for interior lighting and receptacles (120 volts or less circuits) will be copper 600 V, 75 degree Type THHN insulation or equal. Interior lighting (greater than 120 volts) and all exterior lighting wire will be 90° C Type XHHW-2.

E.3.2.3.9 Grounding Cable. Grounding cable will be insulated or uninsulated bare copper conductor sized as required.

E.3.2.3.10 Switchboard and Panel Cable. Switchboard and panel cable will be insulated to 600 V. Cable will be NEC Type SIS or XHHW-2, meeting the UL VW-1 flame test.

E.3.2.3.11 Special Cable. Special cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular manufacturer. Special cable will be routed in accordance with the manufacturer's recommendations.

E.3.2.3.12 Miscellaneous Cable. If other types and constructions of cable are required as design and construction of the unit progress, they will be designated and routed as required.

E.3.2.4 Testing Requirements

Preoperational tests will be performed on insulated conductors after installation, as follows:

- Insulated conductors with insulation rated 5,000 volts and above will be given a field DC insulation test.

- Low voltage cables will be either insulation-resistance tested before connecting to equipment or functionally tested (at equipment operation voltage) as part of the checkout of the equipment system.

- Insulated conductors will be continuity-tested for correct conductor identification.

E.3.2.5 Installation

Cable installation will be in accordance with the following general rules:

- Cables will be routed as indicated in the circuit list. Each circuit will be assigned an unique number.

- The pulling tension of cable will not exceed the maximum tension recommended by the cable manufacturer, and the sidewall pressure at a bend will not exceed the cable manufacturer's recommendations. Maximum bend radii will not exceed the manufacturer's recommendations.

- Care will be exercised during the placement of all cable to prevent tension and bending conditions in violation of the manufacturer's recommendations.

- All cable supports and securing devices will have bearing surfaces located parallel to the surfaces of the cable sheath and will be installed to provide adequate support without deformation of the cable jackets or insulation.

- Nylon ties will be used to neatly lace together conductors entering panelboards, control panels, and similar locations after the conductors have emerged from their supporting raceway and before they are attached to terminals.

- The electrical construction contractor will identify both ends of all circuits. He will also identify all circuits at manholes and handholes.

- All spare conductors of a multi-conductor cable will be left at their maximum length for possible replacement of any other conductor in the cable. Each spare conductor will be neatly coiled and taped to the conductors being used.

- In addition to the above requirements, cables will be installed in accordance with the manufacturer's requirements and recommendations.

E.3.2.6 <u>Connectors</u>

This subsection defines methods of connecting cable between electrical systems and equipment. In this subsection, the term "connector" is applied to devices that join two or more conductors or are used to terminate conductors at equipment terminals for the purpose of providing a continuous electrical path.

Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic action between metals.

All medium voltage and low voltage connectors will be pressure type and secured by using a crimping tool. The tool will be a ratchet type and a product of the connector manufacturer made for the particular connector to be installed. The tool will produce a crimp without damage to the conductor, but will assure a firm metal to metal contact.

Medium voltage cables require stress cones at the termination of the cables. Stress cones will be of the preformed type suitable for the cable to which they are to be applied.

Cables will not be spliced in cable trays or conduits. Control and low-level instrument cable will be spliced only at pigtails and at the transition to high temperature wire. Connections will be made in conduit outlet fittings or junction boxes utilizing terminal blocks or an appropriate connector.

E.3.3 Protective Relaying

The selection and application of protective relays is discussed in the following paragraphs. These relays protect equipment in the Auxiliary Power Supply System, Generator Terminal System, Primary Power Supply System, Turbine-Generator System, and the electrical loads powered from these systems.

The following general requirements apply to all protective relay applications:

- The protective relaying scheme will be designed to remove or alarm any of the following abnormal occurrences:

  - Overcurrent.
  - Undervoltage or overvoltage.
  - Frequency variations.
  - Overtemperature.
  - Abnormal pressure.
  - Open circuits and unbalanced current.

 – Abnormal direction of power flow.

- The protective relaying system will be a coordinated application of either individual relays, multifunction relays, or a combination of individual and multifunction relays. For each monitored abnormal condition, there will exist a designated primary device for detection of that condition. A failure of any primary relay will result in the action of a secondary, overlapping scheme if possible to detect the effect of the same abnormal occurrence. The secondary relay may be the primary relay for a different abnormal condition. Alternate relays may exist which detect the initial abnormal condition but which have an inherent time delay so that the alternate relays will operate after the primary and secondary relays. Similar to secondary relays, the alternate relays may be primary relays for other abnormal conditions. All protective relays will be selected to coordinate with protective devices supplied by manufacturers of major items and the thermal limits of electrical equipment, such as transformers and motors.

- Secondary current produced by current transformers will be in the five ampere range, and voltage signals produced by potential transformers will be in the 120 volt range.

E.3.3.1 <u>Generator Protective Relays</u>

Generator protective relay packages will be furnished in accordance with the particular manufacturer’s requirements. In general, protective relay packages will be provided to minimize the effects from the following faults and malfunctions:

- Generator phase faults.
- Generator stator ground faults.
- Stator open circuits and unbalanced currents.
- Loss of excitation.
- Backup protection for external system faults.
- Reverse power.
- Generator potential transformer circuit monitoring.
- Underfrequency/overfrequency.
- Breaker failure.
- Inadvertent energization of the generator from the system.

In general, equipment furnished with the generator's excitation equipment will provide the following additional protection:

- Underexcitation.
- Overexcitation.

- Generator field ground faults.
- Excessive volts per hertz.
- Exciter field ground faults.

Additional generator protective monitoring equipment will be provided to protect against the following:

- High bearing temperatures.
- Overspeed conditions.
- Excessive vibrations.
- Generator overheating.

A typical complement of protective relays for the turbine generator may be as follows. The actual protective relaying to be used will be developed during design stages:

Generator Differential Relay (Device 87-G1). A generator differential relay will provide primary generator protection against three-phase and phase-to-phase faults within the generator. This relay will not detect ground faults within its zone of protection.

Generator Ground Relays (Device 64-G). Device 64-G will be a low voltage pickup, overvoltage relay which will sense voltage across the generator neutral grounding transformer secondary resistor when a ground fault occurs in the generator, isolated phase bus duct, generator transformer low voltage windings, auxiliary transformer high voltage windings, or the surge protection and potential transformer equipment.

Negative Sequence Relay (Device 46). The negative sequence relay provides protection against unbalanced phase currents, which result from unbalanced loading, unbalanced faults, a turn-to-turn winding fault, and an open circuit. Negative sequence currents exceeding the generator allowable limits result in overheating of the generator rotor.

Loss-of-Field Relays (Device 40). The loss-of-field relay complete with timer will provide protection against thermal damage caused by underexcitation and loss-of-field. These relays provide backup protection for excitation system protective devices furnished with the generator.

Reverse Power Relays (Device 32). Reverse power relays (Device 32) will provide protection of the turbine generator by detection of reverse power flow and motoring of the generator. Reverse power proven (Device 32) will initiate a normal sequential shutdown.

Voltage Balance Relays (Device 60). The voltage balance relay (Device 60) will monitor potential transformer circuits to the generator voltage regulator and protective relays. Upon loss of relaying potential, Device 60 will disable the loss-of-field relay (Device 40) to avoid false tripping of the unit. Upon loss of potential to the voltage regulator, Relay 60 will transfer the voltage regulator from the automatic to manual mode of operation. An alarm will be actuated upon loss of either potential.

Underfrequency and Overfrequency Relays (Device 81). Underfrequency and overfrequency conditions will be detected by Device 81.

Overvoltage and Undervoltage Protection (Devices 27 and 59). The voltage regulator and excitation system include interlocks and protective circuits to prevent operating the generator beyond its design limits. An undervoltage relay (Device 27) and an overvoltage relay (Device 59) will alarm if the voltage regulator fails to maintain voltage within design limits.

Field Ground Fault Protection (Device 64F). Grounds on the generator field will be alarmed by Device 64F.

Generator Backup Distance Relay (Device 21G). This relay will provide backup protection against external system faults. This relay will operate only if an external system fault persists after all other primary system relays, including breaker failure, have failed to operate. This relay will trip the generator lockout relay.

Inadvertent Back Energization Protection (Device 50/27). This relay will provide protection of the generator against inadvertent energization when it is at standstill, on turning gear, or coasting to a stop.

Breaker Failure Relay (Device 50BF). This relay will provide protection against the generator breaker failing to open. This relay will operate when an external system fault persists after all other primary systems have failed to open the generator breaker.

E.3.3.2 Power Transformer Relays

E.3.3.2.1 Generator Transformer. The generator transformers are protected against the effects of the following conditions:

- Phase faults.
- Ground faults.
- Sudden pressure.

This protection will be provided by the relays, which are discussed in the following paragraphs.

Device 87-T1 is a differential relay that provides transformer primary protection by detection of three-phase and phase-to-phase faults in the generator transformer low voltage delta-connected windings, and three-phase, phase-to-phase, and phase-to-ground faults in the generator transformer high voltage wye-connected windings.

Device 51-TN will provide sensitive backup protection for ground faults in the external system.

A rapid increase in pressure within the transformer tank associated with an internal fault will be detected by a sudden-pressure relay, Device 63-T1. This relay will be furnished with the transformer.

Loss of cooling and resulting high temperature will be alarmed.

E.3.3.2.2 Auxiliary Transformer. The auxiliary transformer is protected against the effects of the following conditions:

- Phase faults.
- Ground faults.
- Sudden pressure.

This protection will be provided by the following relays, which are discussed in the following paragraphs.

Device 87 provides primary protection for the high voltage and low voltage windings of the auxiliary transformers and for the cable connecting each low voltage winding to each incoming main breaker in the plant metal-clad switchgear lineups. These relays offer protection against phase-to-phase and three-phase faults. Device 87 is relatively insensitive to ground faults on the secondary side of the transformer should the fault current magnitudes be less than the maximum available ground fault current.

The one time overcurrent relay (Device 51/N) is connected to the bushing current transformer on the neutral of the low voltage winding of the auxiliary transformer. This relay provides primary overload protection to its neutral winding's resistor for ground faults on the switchgear buses or on feeders emanating from the switchgear lineups. This relay also provides backup protection for ground faults in the transformer low voltage winding, in the cable, on the switchgear buses, or on feeders emanating from the switchgear lineups.

A rapid increase in pressure within the transformer tank associated with an internal fault will be detected by a sudden-pressure relay, Device 63. This relay will be furnished with the transformer. Loss of cooling and resulting high temperature will be alarmed.

E.3.3.3 <u>Metal-Clad Switchgear</u>

The protective relays used in the 4,160 volt metal-clad switchgear lineups are discussed in the following paragraphs.

E.3.3.3.1 <u>Incoming Breakers</u>. Each incoming breaker will have time overcurrent relays (Device 51) and a time overcurrent ground detection relay (Device 51N). Device 51 will detect and trip the respective switchgear incoming breaker for sustained overloads and short-circuit currents on the switchgear bus. These relays will provide backup protection for faults on feeders emanating from the switchgear lineups. Device 51N will be residually connected to switchgear current transformers and provide primary protection for ground faults on the switchgear bus and backup protection for ground faults in feeders emanating from the switchgear lineup.

The medium voltage switchgear bus will have undervoltage relays (Device 27) or transducers to detect bus voltage drops to a preset level.

E.3.3.3.2 <u>Secondary Unit Substation Feeders</u>. Each secondary unit substation transformer will be protected by a 4.16 kV breaker and a Multilin solid-state multifunction protective relay. The Multilin will provide primary equipment and cable time overcurrent, instantaneous overcurrent, open phase, and zero sequence protection. Both the longtime and instantaneous elements for phase protection will be adjustable.

E.3.3.3.3 <u>Motor Feeders</u>. Each single speed induction motor feeder will be protected by main fuses and a Multilin solid-state multifunction protective relay. The Multilin protective relay will provide primary equipment and cable time phase/ground time overcurrent (51/51N), phase/ground overcurrent (50/50N), and negative sequence (46) protection.

E.3.3.4 <u>480 Volt Secondary Unit Substation Switchgear</u>

Overload and fault protection for loads connected to the 480 volt load center switchgear will be provided by solid-state trip devices (SSTDs), which are an integral part of drawout air circuit breakers.

Breakers supplying motors or other devices that do not require coordination with downstream trip devices will have adjustable long-time and instantaneous elements for phase protection and will include ground fault protection.

Main breakers, tie breakers (if any), and breakers supplying motor control centers (MCCs) or other loads that contain trip devices will have adjustable long-time and short-time SSTD elements for phase protection and will include ground fault protection. The pickup point and time settings will be adjustable to allow for proper coordination with all downstream trip devices.

Sustained undervoltage in the 480 volt secondary unit substation switchgear bus will be detected by undervoltage relays (Device 27) or transducers.

E.3.3.4.1 <u>480 Volt Motor Control Centers</u>. MCCs will be protected by the 480 V switchgear feeder breakers, which have adjustable long-time and short-time SSTD elements for phase protection and ground fault protection in a manner similar to that described in Subsection 3.3.4, 480 Volt Secondary Unit Substation Switchgear. The SSTD will protect the MCC feeder circuit and the bus against sustained short-circuit currents and serve as backup protection for MCC feeder circuits.

Each magnetic starter within a MCC that supplies power to a motor will have an adjustable motor circuit protector and a thermal overload element in the starter.

Certain nonmotor loads will be fed from MCC feeder circuit breakers. The feeder breakers will be thermal-magnetic molded-case breakers sized to protect supply cable and individual loads.

E.3.3.4.2 <u>480 Volt Power Panels</u>. Power panels will have thermal-magnetic circuit breakers sized to protect supply cable and individual loads.

E.3.4 Classification of Hazardous Area

Areas where flammable and combustible liquids, gases, and dusts are handled and stored will be classified for the purpose of determining the minimum criteria for design and installation of electrical equipment to minimize the possibility of ignition. The criteria for determining the appropriate classification are specified in NEC Article 500 (NFPA 70/ANSI C1).

In addition to defining hazardous areas by class and division, each hazardous element is also assigned a group classification (A, B, C, etc.). The group classifications of hazardous elements are specified in NEC Article 500 and NFPA Standard 497M.

Electrical equipment in areas classified as hazardous will be constructed and installed in accordance with NEC Articles 501 and 502.

References for use in classification of areas, as well as specification of requirements for electrical installation in such areas, include:

- NESC, ANSI C2.
- NEC, ANSI C1, NFPA 70/ANSI C1.
- NFC, NFPA.

E.3.5 Grounding

The station grounding system will be in an interconnected network of bare copper conductor and copper-clad ground rods. The system will protect plant personnel and equipment from the hazards that can occur during power system faults and lightning strikes.

The station grounding grid will be designed for adequate capacity to dissipate heat from ground current under the most severe conditions in areas of high ground fault current concentrations, with grid spacing such that safe voltage gradients are maintained.

Bare conductors to be installed below grade will be spaced in a grid pattern to be indicated on the construction drawings prepared during detailed design. Each junction of the grid will be bonded together by an exothermal welding process.

Grounding stingers will be brought through the ground floor and connected to the building steel and selected equipment. The grounding system will be extended, by way of stingers and conductor installed in cable tray, to the remaining plant equipment. Equipment grounds will conform to the following general guidelines:

- Grounds will conform to the NEC and NESC.

- Major items of equipment, such as switchgear, secondary unit substations, motor control centers, relay panels, and control panels, will have integral ground buses which will be connected to the station ground grid.

- Electronic panels and equipment, where required, will be grounded utilizing an insulated ground wire connected in accordance with the manufacturer's recommendations. Where practical, electronics ground loops will be avoided. Where this is not practical, isolation transformers will be furnished.

- Motor supply circuits to 460 volt motors, which utilize three-conductor cable with a ground in the interstices, will utilize this ground for the motor ground. For 460 volt motor supply circuits, which utilize three single-conductor cables, a separate ground conductor will be utilized.

- All 4,160 volt motors will have a minimum of one 1/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.

- All ground wires installed in conduit will be insulated.

Remote buildings and outlying areas with electrical equipment will be grounded by establishing local subgrade ground grids and equipment grounding systems in a manner similar to the plant area. Remote grids, where practical, will be interconnected with the station ground grid to reduce the hazard of transferring large fault potentials to the remote area through interconnecting instrumentation and communication cable shields.

E.3.5.1 Materials

Grounding materials furnished are described in the following:

- Rods will be copper. Ground rod length and diameter will be determined by soil resistivity and subsurface mechanical properties. Where required ground rod length exceeds 10 feet, standard sections will be exothermally welded together using a guide clamp.

- Cable will be soft-drawn copper with Class B stranding or copper-clad steel.

- Exothermal welds will use molds, cartridges, and materials as manufactured by Cadweld or an equivalent.

- Clamps, connectors, and other hardware used with the grounding system will be made of copper and purchased from an approved supplier.

- Ground wires installed in conduit will be soft-drawn copper with Class B stranding, and green colored 600 volt PVC insulation.

E.3.6 Site Lighting

The site lighting system will provide personnel with illumination to perform general yard task, safety, and plant security. Power used to supply outdoor roadway and area lighting fixtures will be 208 volts or 277 volts.

E.3.6.1 Light Sources

The lighting system will be designed to provide illumination levels recommended by the following standards and organizations:

- IES RP - Standard Practice for Industrial Lighting.
- IES RP - Standard Practice for Roadway Lighting.
- IES RP - Standard Practice for Lighting Offices Containing Computer Display Terminals.

Light source size and fixture selections will be based on the applicability of the luminaries for the area under consideration during detail design.

E.3.6.2 Roadway and Area

Roadway and area lighting will be designed using high-pressure sodium light sources. The light fixtures will be the cutoff type designed to control and direct light within the property line of the facilities. Roadway light fixtures will be installed on hot-dip galvanized steel poles. Local task lighting will be installed on buildings or equipment.

E.3.6.3 Lighting Control

Electric power to outdoor light fixtures will be switched on and off with photoelectric controllers. Local task lighting will be controlled with photoelectric controllers and manual switches at the task.

E.3.7 Freeze Protection (Not Required)

E.3.8 Lightning Protection

Lightning protection will be provided as required for stacks and tops of tall buildings.

Lightning protection for stacks will consist of air terminals provided at radial intervals around the top of the stack. The air terminals will be connected together by copper cable and connected to the plant ground grid with not less than two copper down conductors. Protection against side strokes will be considered for obstruction lighting, antennas, and external elevators.

Lightning protection for tall buildings will consist of air terminals installed on the roof. The air terminals will be connected together with copper cable and connected to the plant ground grid with copper down conductors. Air terminals will be arranged to provide protection for roof penetrating devices, such as piping, air moving equipment, etc.

E.3.9 Raceway and Conduit

The design and specifications for the raceway and conduit systems used in supporting and protecting electrical cable will be in accordance with the provisions of the NEC.

E.3.9.1 Cable Tray

All cable trays except electronic trays will be of trough or ladder type construction with a maximum rung spacing of six inches, nominal depths of four to six inches, and various widths as required. There will be a maximum spacing of eight feet between cable tray supports, except fittings (elbows, tees, etc.) which will be supported in accordance with standards.

Cable tray fittings will have a radius equal to or greater than the minimum bending radius of the cables they contain.

Solid bottom trays will be provided for all electric systems such as special noise-sensitive circuits and analog instrumentation circuits.

Individual tray systems will be established for the following services:

- Medium voltage power cables.
- 600 volt power and control cables.
- Special noise-sensitive circuits or instrumentation cables.

The summation of the cross-sectional areas of cable in tray will be limited to 30 percent of the usable cross section of the tray for medium voltage power cables and to 40 percent for 600 volt power and control cables and electronic cables.

The minimum design vertical spacing for trays will be 12 inches measured from the bottom of the upper tray to the top of the lower tray. At least a nine inch clearance will be maintained between the top of a tray and beams, piping, or other obstacles to facilitate installation of cables in the tray. A working space of not less than 24 inches will be maintained on at least one side of each tray.

Ventilated covers will be provided for vertical trays. Solid covers will be provided for all solid bottom tray and for all outdoor tray. Solid covers will also be provided for the top tray of horizontal tray runs located under grating floor or insulated piping.

E.3.9.2 Conduit

Conduit will be used to protect conductors routed to individual devices, in hazardous areas, and where the quantity of cable does not economically justify the use of cable tray.

Electrical Metallic Tubing (EMT) will be used indoors in nonhazardous areas for lighting branch circuits and communication circuits.

Polyvinyl chloride conduit will be used for underground duct banks and some below grade concrete encased conduit.

Liquidtight flexible metallic conduit will be used for connections to accessory devices such as: solenoid valves, limit switches, pressure switches, etc.; for connections to motors or other vibrating equipment; and across areas where expansion or movement of the conduit is required.

All other conduit, unless specific environmental requirements dictate the use of plastic or aluminum conduit, will be rigid galvanized steel.

Exposed conduit will be routed parallel or perpendicular to dominant surfaces with right angle turns made of symmetrical conduit bends or fittings.

Conduit will be routed at least six inches from the insulated surfaces of hot water, steam pipes, and other hot surfaces.

Conduit will be sized in accordance with the conduit fill requirements of the National Electrical Code.

Conduit will be securely supported within three feet of connections to boxes and cabinets.

Conduit larger than one-half inch and up to 1.25 inches will be supported by supports with a maximum separation of eight feet. Conduit 1.5 inch and larger will be supported by supports located at least every 10 feet.

E.3.9.3 <u>Duct Bank and Manholes</u>

Underground duct banks will be used for cable routed between outlying areas and other remote areas as necessary.

All underground duct banks will consist of PVC tubing encased in reinforced concrete. The nominal diameter of the plastic ducts will be four inches. A three inch or larger galvanized steel conduit will also be installed where required for analog low-level circuits requiring noise immunity from adjacent power circuits.

All underground duct banks will be installed in accordance with the following methods:

- Ducts will be sloped not less than three inches per 100 feet to manholes to provide adequate drainage. Low spots in duct runs will be avoided.

- Reinforcing steel will not form closed magnetic paths between ducts. Nonmetallic spacers will be used to maintain duct spacing.

Reinforced concrete manholes and electrical vaults will be provided, where required, so that cable may be installed without exceeding allowable pulling tensions and cable sidewall pressures. Each manhole will have the following provisions:

- Provisions for attachment of cable pulling devices.

- Provisions for racking of cables.

- Manhole covers of sufficient size to loop feed the largest diameter cable through the manhole without splicing.

- Sealed bottoms and sumps.

Conduit from manholes to the equipment at remote locations will be changed to rigid steel prior to emerging from below grade. All below grade steel conduit will be wrapped and encased in concrete.

Ductbank and manholes will be designed in accordance with the seismic criteria defined in Appendix B, Structural and Seismic Engineering Design Criteria.

Duct banks will be designed to include spare capacity after completion of installation to allow for future growth and expansion.

E.3.10 Battery System

The batteries used for the DC power supply system for the balance-of-plant loads will consist of 125 volt pressure regulated type batteries.